PATENT SPECIFICATION

(11) 1 366 050

1 366 050

(21) Application No. 42732/72 (22) Filed 14 Sept. 1972

(23) Complete Specification filed 14 Sept. 1973

(44) Complete Specification published 11 Sept. 1974

(51) International Classification G01S 9/66

(52) Index at acceptance
H4D G3B G3M G4A5 G7D

(72) Inventor ALEXANDER RANKIN CORNFORTH

(19)

(54) IMPROVEMENTS IN OR RELATING TO ULTRASONIC THICKNESS MEASUREMENT

(71) We, BRITISH STEEL CORPORATION, a Corporation incorporated and existing under the Iron and Steel Act 1967 of 33, Grosvenor Place, London S.W.1, do hereby declare the invention for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to ultrasonic thickness measurement.

The use of an ultrasonic pulse echo technique for thickness measurement of products is known, for example, in the measurement of metal tube wall thickness for quality control purposes. The technique employs the measurement of the time span between successive ultrasonic reflections between appropriate opposing boundries of the product.

To measure the time span between two successive reflected pulses can lead to significant errors if the time interval is small, as is usually the case, particularly when measuring metal tube wall thickness. It has therefore been proposed to measure the time span over a plurality of signals. However such an arrangement still involves a number of problems. Thus, for example, extraneous signals between major reflections can be introduced due to sonic wave mode conversion, or interference effects of sonic waves within the product can lead to the loss of one or more reflection signals.

All of these will lead to serious errors in the resultant thickness reading.

It is an object of the present invention to overcome or at least substantially reduce these problems.

According to one aspect of the invention there is provided apparatus for the ultrasonic thickness measurement of a product comprising ultrasonic transducing means for emitting ultrasonic pulses into the product and detecting reflections thereof; timing means for measuring the time span of a predetermined plurality of reflected pulse signals and for separately measuring the time span of a predetermined lesser number of reflected pulse signals within the predetermined plurality of signals; comparator means for comparing the time span of the plurality of signals with the time span of the lesser number of signals; processing means for processing at least one set of the signals before comparison such that at comparison representations of the time spans are, for correct comparison, equal; and product thickness signal output means controlled by the comparator means.

According to another aspect of the invention there is provided a method of measuring the thickness of a product comprising transmitting ultrasonic pulses into the product; receiving a plurality of reflected pulses from within the product; measuring the time span of a predetermined plurality of reflected pulse signals, measuring the time span of a predetermined lesser number of reflected pulse signals within the predetermined plurality of signals; comparing the time span of the plurality of signals with the time span of the lesser number of signals; processing at least one set of the signals before comparison such that at comparison representations of the time spans are, for correct comparison, equal; and controlling an output signal representative of the time span of the predetermined plurality of signals in dependence on the comparison.

The output signal should, ideally, be representative of the thickness of the product since the time span for the plurality of signals should be a simple multiple of time between the receipt of two successive pulses reflected across the thickness of the product, as also should the representation of the time span of the said lesser number of signals. Hence the comparison between

the two time spans should reveal a simple predetermined relationship between them. However if the plurality of reflected pulse signals incorporates one or more extraneous signals, or if one or more reflected pulse signals has been lost, this simple relationship will not be found upon comparison, so that the output signal can be rendered void. Hence by means of the invention it is possible to know whether the output signal is a true representation of the product thickness, and to ensure that only correct output signals are passed.

The comparison means can be arranged to control gating means such that an output signal will only be passed if said comparison shows the predetermined required relationship.

Conveniently, the predetermined lesser number of reflected pulses is arranged to be two consecutive pulse signals, so that, assuming no extraneous signals are included and no signals are lost, the time span of the said plurality of signals is a simple multiple of the time span between the two signals.

Where the predetermined lesser number of signals is two, the processing of the signals can be done, for example, by multiplying the representation of the span of the two signals by a factor of the number of signals in the predetermined plurality of signals less one before comparison, or alternatively by dividing the signal representative of the predetermined plurality of signals by a factor of the number of signals in the predetermined plurality of signals less one before comparison.

The signals representative of the two time spans may be converted to digital frequency pulses before comparison, e.g. the signals may be arranged to gate a clock pulse source for a time representative of the respective time span, the comparison then being between the two sets of pulses.

In this case, it is necessary to provide that, for a correct comparison, the number of pulses in each set is equal at comparison. This may be done by arranging to multiply or divide by an appropriate number the frequency of pulses from the pulse source for use with the time span of the predetermined plurality of signals or the predetermined lesser number of signals respectively.

In order that the invention may be more readily understood, one embodiment thereof will now be described by way of example with reference to the accompanying drawings in which:—

Figure 1 is a block diagram representative of the circuit of one embodiment of the invention;

Figure 2 is a diagram representing the operational time factors of the embodiment of Figure 1; and

Figure 3 is a block diagram representative of the circuit of a modification of the embodiment of Figure 1.

In the arrangement shown in Figures 1 and 2 the transmitter Tx supplies a high voltage driving pulse to the ultrasonic transducer 1. The resultant ultrasonic transmission pulse is coupled to a product (not shown) and the resultant successive echoes within the workpiece produce corresponding electrical signals on reception by the transducer 1. These reflection signals are passed to the receiver Rx where they are suitably amplified and transformed into video pulses. A pulse shaper 2 is used to improve the leading edge of the video pulses before they are passed to a primary pulse counting unit 3. In the primary pulse counting unit 3, the 3rd, 4th and 6th pulses of the reflected signal pulse train from the pulse shaper 2 are electronically extracted. The 3rd and 4th pulses are passed via lines 4 and 5, to a flip-flop (bi-stable) 1, the output of which is a square wave form whose output time is equivalent to the time interval between the 3rd and 4th pulses. This waveform is passed to a times 3 pulse stretcher 8; which is esentially a constant current capacitor charging device which expands the time interval output of flip-flop 1 by a factor of 3, such that the original time interval between 3rd and 4th pulses of the pulse train is now multiplied by the factor 3. This expanded output is passed to and operates gate 1, which allows a 'burst' of pulses from a clock pulse source 9 through the gate during the expanded time interval.

The number of pulses contained within this 'burst' is counted by pulse counting unit 1 and the resultant count held. In a similar manner, the 3rd and 6th pulses from the primary counting unit are passed via lines 6 and 7, to flip-flop 2 where the output waveform time interval corresponds to the time interval between the 3rd and 6th pulses. The output from flip-flop 2 is passed to gate 2 which allows a 'burst' of pulses from the clock pulse source 9 through the gate during the time interval between the 3rd and 6th pulses. The number of pulses contained within this burst is counted by pulse counting unit 2. The counts held in pulse counting units 1 and 2 are electrically compared by the count comparator 10. If the counts are essentially equal (i.e. within predetermined limits) when the count comparator is measuring, a measurement (or count) valid signal output from the count comparator 10 is fed to the print enable system of a recorder 11 which allows the accurately measured workpiece thickness data (by accurate measurement of the 3rd and 6th pulse time interval) to be printed on the recorder 11. The counters

are then reset and held ready for the next transmitter cycle.

Figure 2 is a timing diagram of the embodiment of the invention of Figure 1 showing the operation in three separate circumstances. On the left is shown the operation when a correct train of reflection pulse signals are involved. In the centre an extraneous signal has been included whilst on the right one pulse signal is missing.

Line 20 shows the input driving pulse supplied by transmitter Tx to the transducer 1 in each of the three cases. Line 21 shows the pulse signal output from receiver Rx, the extra pulse and the missing pulse respectively being clearly indicated in the centre and on the right. Line 22 shows each of the three cases after the signals have passed through the pulse shaper 2. Lines 23, 24 and 25 indicate on a time scale the third, fourth and sixth pulse signals respectively upon extraction at the primary pulse counting unit 3. Line 26 shows, in each of the three cases, the square waveform signal provided by the third and fourth pulse signals at the output from flip-flop 1, and line 27 shows the same signals at the output from the pulse stretcher 8. Line 28 shows the square wavefrom signal provided by the third and sixth pulse signals at the output from flip-flop 2. Lines 29 and 30 show the gated pulses from the clock pulse source 9 at the outputs of gate 1 and gate 2 respectively prior to being fed to pulse counting units 1 and 2 respectively. Upon comparison in the comparator 10, only the pulses on the left will provide a correct comparison. The pulses in the centre and on the right will result in a void comparison.

The embodiment of the invention shown in Figure 3 is similar to that of Figure 1, in that a transducer 12 is excited by the transmitter Tx and the resultant reflection signals processed through a receiver amplifier Rx and pulse shaper 13 and then to a primary pulse counting unit 14 where the 3rd, 4th and 6th pulses are extracted as before. The output waveform of flip-flop 1 is again essentially the time interval between the 3rd and 4th pulses, and the output of flip-flop 2 of the time interval between the 3rd and 6th pulses. These waveforms are fed to Gates 1 and 2 respectively where Gate 1 is also fed directly from a high frequency clock pulse source 14 and gate 2 is fed from the high frequency clock pulse source 15 via a divide by three frequency division unit 16. The resultant outputs from gates 1 and 2 are counted on pulse counting units 1 and 2 and the counts held and then compared as in the system described in Figure 1.

In some cases it is desirable to provide a further check on the thickness measuring arrangement, as will now be explained.

As already described, the successive reflected signals within the product are passed to the receiver Rx where they are suitably amplified and transformed into video pulses. Transforming the RF pulses into video pulses can be achieved in a number of ways, but primarily two principles can be used, i.e. edge detection of the RF pulses or turnover detection of the RF pulses.

Where edge detection is used difficulties can arise in determining the leading edge of the RF pulses particularly on the small amplitude signals at the far end of the pulse train. If for example, the product thickness measurement is determined by the measurement of the time interval between the third and sixth pulses, an error in measurement is possible if the 6th pulse is of low amplitude due to say high attenuation in the material of the product.

This problem can be overcome if the seventh pulse of the pulse train is extracted, and this pulse is used to enable the thickness measurement read out along with the count valid system as previously described. This facility ensures that, if the seventh pulse has been detected then the sixth pulse is reasonably well established and thus minimises the likelihood of an edge detection error on the sixth pulse.

WHAT WE CLAIM IS:—

1. Apparatus for the ultrasonic thickness measurement of a product comprising ultrasonic transducing means for emitting ultrasonic pulses into the product and detecting reflections thereof; timing means for measuring the time span of a predetermined plurality of reflected pulse signals and for separately measuring the time span of a predetermined lesser number of reflected pulse signals within the predetermined plurality of signals; comparator means for comparing the time span of the plurality of signals with the time span of the lesser number of signals; processing means for processing at least one set of the signals before comparison such that at comparison representations of the time spans are, for correct comparison, equal; and product thickness signal output means controlled by the comparator means.

2. Apparatus according to claim 1 wherein the processing means is arranged to increase the representation of the time span of the predetermined lesser number of signals.

3. Apparatus according to claim 1 wherein the processing means is arranged to reduce the representation of the time span of the predetermined plurality of signals.

4. Apparatus according to any one of the preceding claims wherein the comparison means is arranged to control gating means such that an output signal will only be passed if the comparison is correct.

5. Apparatus according to any one of

the preceding claims including means for converting the two time spans to digital frequency pulses before comparison.

6. Apparatus for the ultrasonic thickness measurement of a product substantially as shown in and as hereinbefore described in relation to the accompanying drawings.

7. A method of measuring the thickness of a product comprising transmitting ultrasonic pulses into the product; receiving a plurality of reflected pulses from within the product; measuring the time span of a predetermined plurality of reflected pulse signals; measuring the time span of a predetermined lesser number of reflected pulse signals within the predetermined plurality of signals; comparing the time span of the plurality of signals with the time span of the lesser number of signals; processing at least one set of the signals before comparison such that at comparison representations of the time spans are, for correct comparison, equal; and controlling an output signal representative of the time span of the predetermined plurality of signals in dependence on the comparison.

8. A method according to claim 7 wherein the representation of the time span of the predetermined lesser number of signals is increased before comparison.

9. A method according to claim 8 wherein the representation of the time span of the predetermined plurality of signals is reduced before comparison.

10. A method according to Claim 7, 8 or 9 wherein the predetermined lesser number of signals is arranged to be two consecutive pulse signals.

11. A method according to any one of claims 7 to 10 in which the two time spans are converted to digital frequency pulses before comparison.

12. A method according to claim 11 wherein the signals are each arranged to gate a clock pulse source for a time representative of the respective time span.

13. A method of measuring the thickness of a product substantially as hereinbefore described with reference to the accompanying drawings.

P. W. M. Heath
Agent for the Applicants

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1974. Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

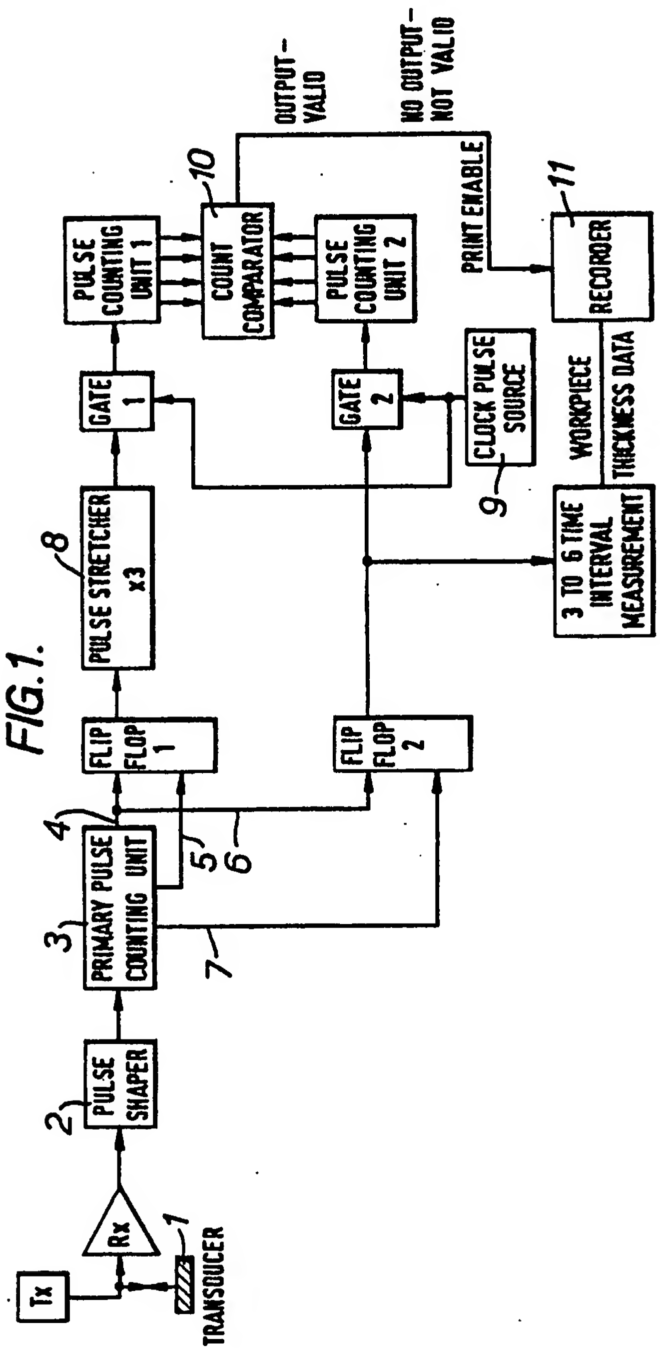
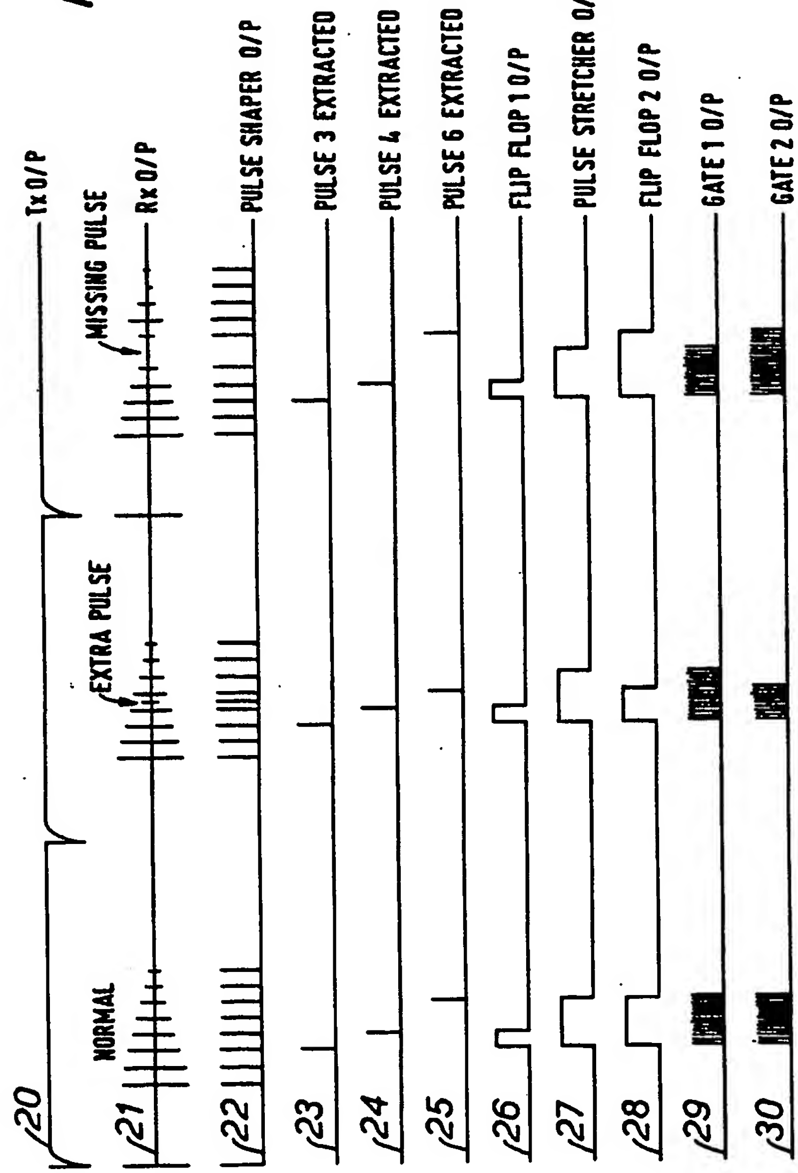

Tx
Rx
TRANSDUCER
1
2
PULSE SHAPER
3
PRIMARY PULSE COUNTING UNIT
4
5
6
7
FLIP FLOP 1
FLIP FLOP 2
8
PULSE STRETCHER x3
GATE 1
GATE 2
9
CLOCK PULSE SOURCE
PULSE COUNTING UNIT 1
PULSE COUNTING UNIT 2
10
COUNT COMPARATOR
OUTPUT-VALID
NO OUTPUT-NOT VALID
PRINT ENABLE
11
RECORDER
WORKPIECE THICKNESS DATA
3 TO 6 TIME INTERVAL MEASUREMENT

FIG.1.

FIG.2.


20
Tx O/P
21
NORMAL
EXTRA PULSE
MISSING PULSE
Rx O/P
22
PULSE SHAPER O/P
23
PULSE 3 EXTRACTED
24
PULSE 4 EXTRACTED
25
PULSE 6 EXTRACTED
26
FLIP FLOP 1 O/P
27
PULSE STRETCHER O/P
28
FLIP FLOP 2 O/P
29
GATE 1 O/P
30
GATE 2 O/P

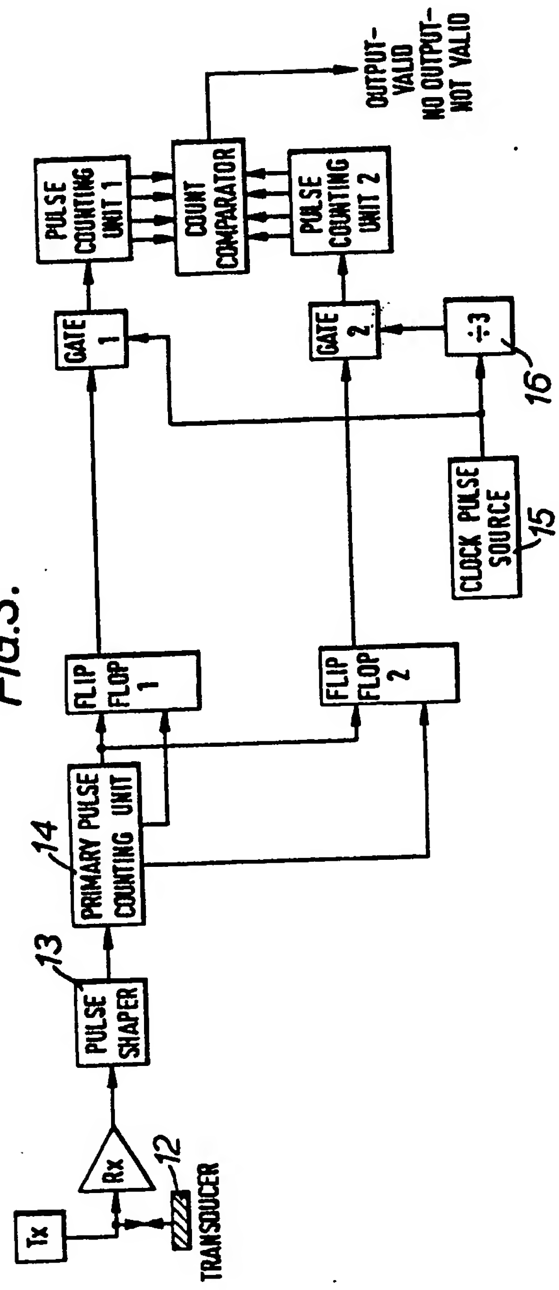

Tx
Rx
12
TRANSDUCER
PULSE SHAPER
13
PRIMARY PULSE COUNTING UNIT
14
FLIP FLOP 1
FLIP FLOP 2
GATE 1
GATE 2
PULSE COUNTING UNIT 1
PULSE COUNTING UNIT 2
COUNT COMPARATOR
OUTPUT-VALID
NO OUTPUT-NOT VALID
CLOCK PULSE SOURCE
15
÷3
16

FIG.3.